PATENT COOPERATION TREAT

From the INTERNATIONAL BUREAU

PCT

NOTIFICATION OF THE RECORDING OF A CHANGE

(PCT Rule 92bis.1 and Administrative Instructions, Section 422)

To:

IBBOTSON, Harry
Motorola, Intellectual Property Operations
Midpoint, Alencon Link
Basingstoke, Hampshire RG21 7PL
ROYAUME-UNI

Date of mailing (day/month/year)
24 September 1999 (24.09.99)

Applicant's or agent's file reference
CE30343P/PCT

IMPORTANT NOTIFICATION

International application No.
PCT/EP98/08120

International filing date (day/month/year)
07 December 1998 (07.12.98)

1. The following indications appeared on record concerning:

[X] the applicant [X] the inventor [ ] the agent [ ] the common representative

Name and Address
MOHEBBI, Behzad
12 Cambridge Park Court
Cambridge Park
Twickenham TW1 2JN
United Kingdom

State of Nationality: GB
State of Residence: GB
Telephone No.:
Facsimile No.:
Teleprinter No.:

2. The International Bureau hereby notifies the applicant that the following change has been recorded concerning:

[ ] the person [ ] the name [X] the address [ ] the nationality [ ] the residence

Name and Address
MOHEBBI, Behzad
12 Cambridge Park Court
Cambridge Park
Twickenham TW1 2NJ
United Kingdom

State of Nationality: GB
State of Residence: GB
Telephone No.:
Facsimile No.:
Teleprinter No.:

3. Further observations, if necessary:
Change of postal code.

4. A copy of this notification has been sent to:

[X] the receiving Office
[ ] the International Searching Authority
[X] the International Preliminary Examining Authority
[ ] the designated Offices concerned
[X] the elected Offices concerned
[ ] other:

The International Bureau of WIPO
34, chemin des Colombettes
1211 Geneva 20, Switzerland
Facsimile No.: (41-22) 740.14.35

Authorized officer
Dorothée Mülhausen
Telephone No.: (41-22) 338.83.38

PATENT COOPERATION TREATY

From the INTERNATIONAL BUREAU

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NOTIFICATION OF ELECTION

(PCT Rule 61.2)

To:

Assistant Commissioner for Patents
United States Patent and Trademark Office
Box PCT
Washington, D.C.20231
ÉTATS-UNIS D'AMÉRIQUE

in its capacity as elected Office

Date of mailing (day/month/year) 16 August 1999 (16.08.99)	
International application No. PCT/EP98/08120	**Applicant's or agent's file reference** CE30343P/PCT
International filing date (day/month/year) 07 December 1998 (07.12.98)	**Priority date** (day/month/year) 17 December 1997 (17.12.97)
Applicant MOHEBBI, Behzad	

1. The designated Office is hereby notified of its election made:

[X] in the demand filed with the International Preliminary Examining Authority on:

28 June 1999 (28.06.99)

[ ] in a notice effecting later election filed with the International Bureau on:

2. The election [X] was

[ ] was not

made before the expiration of 19 months from the priority date or, where Rule 32 applies, within the time limit under Rule 32.2(b).

The International Bureau of WIPO **34, chemin des Colombettes** **1211 Geneva 20, Switzerland**	Authorized officer F. Baechler
Facsimile No.: (41-22) 740.14.35	Telephone No.: (41-22) 338.83.38

Form PCT/IB/331 (July 1992) 2790650

PATENT COOPERATION TREATY

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INTERNATIONAL SEARCH REPORT

(PCT Article 18 and Rules 43 and 44)

Applicant's or agent's file reference	**FOR FURTHER ACTION** see Notification of Transmittal of International Search Report (Form PCT/ISA/220) as well as, where applicable, item 5 below.	
CE30343P/PCT		
International application No.	International filing date *(day/month/year)*	(Earliest) Priority Date *(day/month/year)*
PCT/EP 98/ 08120	07/12/1998	17/12/1997
Applicant		
MOTOROLA LIMITED et al.		

This International Search Report has been prepared by this International Searching Authority and is transmitted to the applicant according to Article 18. A copy is being transmitted to the International Bureau.

This International Search Report consists of a total of 2 sheets.

[X] It is also accompanied by a copy of each prior art document cited in this report.

1. **Basis of the report**

   a. With regard to the **language,** the international search was carried out on the basis of the international application in the language in which it was filed, unless otherwise indicated under this item.

   [ ] the international search was carried out on the basis of a translation of the international application furnished to this Authority (Rule 23.1(b)).

   b. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, the international search was carried out on the basis of the sequence listing :

   [ ] contained in the international application in written form.

   [ ] filed together with the international application in computer readable form.

   [ ] furnished subsequently to this Authority in written form.

   [ ] furnished subsequently to this Authority in computer readble form.

   [ ] the statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.

   [ ] the statement that the information recorded in computer readable form is identical to the written sequence listing has been furnished

2. [ ] **Certain claims were found unsearchable** (See Box I).

3. [ ] **Unity of invention is lacking** (see Box II).

4. With regard to the **title,**

   [ ] the text is approved as submitted by the applicant.

   [X] the text has been established by this Authority to read as follows:

   A METHOD FOR PREDICTING INTERFERENCE IN A FREQUENCY HOPPING CELLULAR COMMUNICATIONS SYSTEM

5. With regard to the **abstract,**

   [X] the text is approved as submitted by the applicant.

   [ ] the text has been established, according to Rule 38.2(b), by this Authority as it appears in Box III. The applicant may, within one month from the date of mailing of this international search report, submit comments to this Authority.

6. The figure of the **drawings** to be published with the abstract is Figure No. _____

   [ ] as suggested by the applicant.

   [ ] because the applicant failed to suggest a figure.

   [ ] because this figure better characterizes the invention.

   [X] None of the figures.

INTERNATIONAL SEARCH REPORT

[redacted] national Application No
[redacted]/EP 98/08120

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 H04Q7/34

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 H04Q

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	WO 94 05097 A (STJERNHOLM PAUL ;TELEVERKET (SE)) 3 March 1994 see page 2, line 25 - page 4, line 33	1,10
A	US 5 293 640 A (GUNMAR KRISTER ET AL) 8 March 1994	

☐ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
26 April 1999	04/05/1999

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Lopez-Pérez, M-C

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Form PCT/ISA/210 (second sheet) (July 1992)

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
PCT/EP 98/08120

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 9405097 A	03-03-1994	SE 469580 B	26-07-1993
		EP 0608394 A	03-08-1994
		SE 9202367 A	26-07-1993
		US 5603092 A	11-02-1997
US 5293640 A	08-03-1994	SE 465246 B	12-08-1991
		SE 465145 B	29-07-1991
		SE 465247 B	12-08-1991
		AT 123607 T	15-06-1995
		AU 627858 B	03-09-1992
		AU 5273590 A	26-09-1990
		CA 2046274 A	04-09-1990
		DE 69019961 D	13-07-1995
		DE 69019961 T	19-10-1995
		EP 0461192 A	18-12-1991
		ES 2072428 T	16-07-1995
		JP 4504038 T	16-07-1992
		SE 8900743 A	04-09-1990
		WO 9010342 A	07-09-1990
		SE 8900744 A	04-09-1990
		SE 8900745 A	04-09-1990

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PATENT COOPERATION TREATY

PCT

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

(PCT Article 36 and Rule 70)

Applicant's or agent's file reference	FOR FURTHER ACTION	See Notification of Transmittal of International Preliminary Examination Report (Form PCT/IPEA/416)
CE30343P/PCT		
International application No.	International filing date *(day/month/year)*	Priority date *(day/month/year)*
PCT/EP98/08120	07/12/1998	17/12/1997
International Patent Classification (IPC) or national classification and IPC H04Q7/34		
Applicant MOTOROLA LIMITED et al.		

1. This international preliminary examination report has been prepared by this International Preliminary Examining Authority and is transmitted to the applicant according to Article 36.

2. This REPORT consists of a total of 10 sheets, including this cover sheet.

   ☐ This report is also accompanied by ANNEXES, i.e. sheets of the description, claims and/or drawings which have been amended and are the basis for this report and/or sheets containing rectifications made before this Authority (see Rule 70.16 and Section 607 of the Administrative Instructions under the PCT).

   These annexes consist of a total of sheets.

3. This report contains indications relating to the following items:

   - I ☒ Basis of the report
   - II ☐ Priority
   - III ☒ Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
   - IV ☒ Lack of unity of invention
   - V ☒ Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations suporting such statement
   - VI ☐ Certain documents cited
   - VII ☒ Certain defects in the international application
   - VIII ☒ Certain observations on the international application

Date of submission of the demand	Date of completion of this report
28/06/1999	29.03.2000
Name and mailing address of the international preliminary examining authority: European Patent Office D-80298 Munich Tel. +49 89 2399 - 0 Tx: 523656 epmu d Fax: +49 89 2399 - 4465	Authorized officer Aullo Navarro, A Telephone No. +49 89 2399 2267

Form PCT/IPEA/409 (cover sheet) (January 1994)

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

International application No. PCT/EP98/08120

I. Basis of the report

1. This report has been drawn on the basis of (*substitute sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this report as "originally filed" and are not annexed to the report since they do not contain amendments.*):

Description, pages:

1-9 as originally filed

Claims, No.:

1-14 as originally filed

Drawings, sheets:

1/4-4/4 as originally filed

2. The amendments have resulted in the cancellation of:

☐ the description, pages:
☐ the claims, Nos.:
☐ the drawings, sheets:

3. ☐ This report has been established as if (some of) the amendments had not been made, since they have been considered to go beyond the disclosure as filed (Rule 70.2(c)):

4. Additional observations, if necessary:

III. Non-establishment of opinion with regard to novelty, inventive step and industrial applicability

The questions whether the claimed invention appears to be novel, to involve an inventive step (to be non-obvious), or to be industrially applicable have not been examined in respect of:

☐ the entire international application.

☒ claims Nos. 1-14 (examination in detail not possible).

because:

☐ the said international application, or the said claims Nos. relate to the following subject matter which does not require an international preliminary examination (*specify*):

☒ the description, claims or drawings (*indicate particular elements below*) or said claims Nos. 1-14 are so unclear that no meaningful opinion could be formed (*specify*):

see separate sheet

☐ the claims, or said claims Nos. are so inadequately supported by the description that no meaningful opinion could be formed.

☐ no international search report has been established for the said claims Nos. .

IV. Lack of unity of invention

1. In response to the invitation to restrict or pay additional fees the applicant has:

   ☐ restricted the claims.

   ☐ paid additional fees.

   ☐ paid additional fees under protest.

   ☐ neither restricted nor paid additional fees.

2. ☒ This Authority found that the requirement of unity of invention is not complied and chose, according to Rule 68.1, not to invite the applicant to restrict or pay additional fees.

3. This Authority considers that the requirement of unity of invention in accordance with Rules 13.1, 13.2 and 13.3 is

   ☐ complied with.

   ☒ not complied with for the following reasons:

   see separate sheet

4. Consequently, the following parts of the international application were the subject of international preliminary examination in establishing this report:

   ☐ all parts.

   ☒ the parts relating to claims Nos. 1-14 (examination in detail not possible).

V. Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Statement

Novelty (N)	Yes:	Claims	1-14
	No:	Claims	
Inventive step (IS)	Yes:	Claims	1-9
	No:	Claims	
Industrial applicability (IA)	Yes:	Claims	1-14
	No:	Claims	

2. Citations and explanations

see separate sheet

VII. Certain defects in the international application

The following defects in the form or contents of the international application have been noted:

see separate sheet

VIII. Certain observations on the international application

The following observations on the clarity of the claims, description, and drawings or on the question whether the claims are fully supported by the description, are made:

see separate sheet

III. Non-establishment of opinion:

1. A detailed examination of the application in respect of novelty and inventive step is not practicable in view of the number and nature of clarity objections raised in Section VIII below. As far as an evaluation of the technical contribution made by the present application over the prior art can be carried out, by interpreting the subject-matter of the present claims with the help of the description, some general comments in respect of novelty and inventive step are made in Section V below (PCT Guidelines I-4.3).

IV. Lack of unity:

1. Without the provision in the independent Claims 1 and 10 of the necessary clarifications and the missing essential features identified in Section VIII below, their present formulation is such that they lack the link necessary to avoid an objection as to lack of unity (Rule 13.1 and 13.2 PCT) that currently applies, since they do not share at present a "single general inventive concept", expressible in terms of the "same or corresponding technical features", as required by Rule 13.2 PCT.

2. However, this is a formal problem derived rather from the clarity problems indicated below (see Section VIII); the introduction of the amendments necessary to overcome the objections as to lack of clarity would automatically render moot the non-unity objection.

V. Statement under Article 35(2) PCT:

Reference is made to the following documents:

D1: WO-A-94 05097
D2: US-A-5 293 640

1. The present application relates to a method of predicting interference experienced by a first cell from one or more further cells in a cellular telecommunications network.

   It is known in the **prior art** of D1 and D2 to perform interference measurements in order to represent the interaction between the cells in a cellular telecommunications network and estimate the interference probability between them. Based on these estimations and other considerations, such as traffic demands, the radio cells can be planned so as to assign them the radio channels and to determine e.g. a frequency reuse pattern being acceptable from the point of view of interference.

   The present application **aims** at optimising the planning of the cells so as to obtain an optimum interference level throughout the network.

2. The **invention** thus lies in that, in addition to estimating the interference levels corresponding to the interference experienced by each cell due to the one or more further cells, probabilities of each cell hopping to the same frequency as each of the further cells are calculated in dependence with the number of frequencies in common between the sets of frequencies used by each cell and the number of frequencies used for hopping; the estimated interference levels are then weighted with the corresponding probabilities thus calculated, and then a frequency hopping parameter determining the number and distribution of frequencies is modified in order to thereby modify the weighted interference levels so as to obtain the desired optimum interference level throughout the network.

3. This particular solution is not disclosed in or rendered obvious by the cited documents.

   Therefore, an inventive step could have been acknowledged in the subject-matter of an independent claim method claim, clarified so as to include the above features, which could have hence been considered to meet the requirements of Article 33(1)-(4) PCT.

VII. Certain defects:

1. In order to meet the requirements of Rule 6.3(b) PCT, any amended independent claim should have been properly cast in the two-part form, having a pre-characterizing portion correctly reflecting the prior art of D1.

   All claims should have included reference signs relating to the technical features referred to therein (Rule 6.2(b) PCT).

2. The opening part of the description should have been modified to bring it into agreement with the amended independent claims that should have been filed (Rule 5.1(a)(iii) PCT). Particular attention should have been paid to avoiding any reference to "the invention" or to "embodiments" thereof in parts of the description not falling within the scope of the claims that should have been filed.

   Documents D1 and D2 should have been acknowledged and briefly discussed in the opening part of the description (Rule 5.1(a)(ii) PCT), so as to put the invention into the proper perspective. Following from the disclosure of documents D1 and D2, the statement of problem in the introductory part of the description should have been revised in a way such that the problems existing in the prior art can be appreciated and the solution provided by the application can be understood (PCT Guidelines II-4.4 and II-4.6).

   A revision of the description should have been carried out, in order to identify as such terms which may correspond to trade marks (e.g., on pages 3 and 4).

3. The application should have also been revised with an aim at correcting possible clerical errors (e.g., on page 8, which refers in its second paragraph to steps 408 and 410, instead of steps 308 and 310).

4. The present drawings do not meet the requirements of Rule 11.2(a), 11.6(c), 11.11(b), 11.13(a), 11.13(c), 11.13(e), 11.13(f) and 11.13(h) PCT. Hence, a set of formal drawings should have been filed in accordance with the requirements of Rule 11 PCT.

VIII. Certain observations:

1. The scope of independent Claims 1 and 10 is unclear, due to the presence of vague and undefined expressions, which do not permit to determine the matter for which protection is sought (PCT Guidelines III-4.1).

1.1 In this respect, the term "parameter" in Claim 1 is unclear, while according to the description on page 8, lines 15-20, it is possible to use a more precise definition, to refer to a frequency hopping parameter determining the number and distribution of frequencies.

1.2 The term "calculations" in Claim 10 is vague and indefinite and, as such, renders the scope of the claim unclear. In this respect, it is clear from the description on pages 8 and 9, as well as from Figure 5, that Claim 10 should have been directed to the use of a probability distribution representing a further enhancement of the general case of having further cells (according to dependent Claim 6), such that the probabilities according to the "calculating"-step (of Claim 6) are modelled in Claim 10 according to a probability distribution representing the probability of cells in the network hopping to the same frequency, wherein each of the probabilities in the model are then assigned to each cell on the basis of the estimated interference level determined for each cell. Thus, it would have been possible to redraft Claim 10 as a further dependent claim referring back to Claim 6, or else as an independent claim combining the features in present Claims 6 (except the "calculating"-step) and 10 (features replacing the "calculating"-step, as indicated above).

1.3 In addition, the term "substantially" included in Claims 1 and 10 is vague and ambiguous and should have hence been deleted, since it renders their scope unclear. The same objection applies also to the presence of this term in Claim 6, which should have also been avoided.

2. Moreover, the present claims do not meet the requirement following from Article 6 PCT taken in combination with Rule 6(3)(b) PCT that any independent claim must contain all the technical features essential to the invention.

2.1 In the case of Claim 1, it is clear from the description on page 6, lines 22-25, that the probabilities to be calculated in the "calculating"-step are dependent on the number of frequencies in common between the sets of frequencies used by each cell, and the number of frequencies used for hopping. The same features are also essential to define the general "calculating"-step applicable to further cells in the case of Claim 6.

2.2 Likewise, the "modifying"-step in Claim 1 should have been clarified, by adding the features which according to the description (page 8, lines 16-20) are essential to define the performance of the invention. This applies also to the corresponding step in Claim 6.

In particular, the "modifying"-step should have indicated that the frequency hopping parameter determining the number and distribution of frequencies (see paragraph 1.1 above) is modified in order to modify the weighted interference level (and the further weighted interference levels in the case of Claim 6) so as to obtain an optimum interference level throughout the network.

3. Other clarity problems which should have been attended to are the following:

3.1 The back references in Claims 7 and 8 ("any one of the preceding claims") are unclear, because of the feature combinations they represent. In this respect, it is clear from the wording of these claims that Claim 7 should have referred back to Claim 6 only (wherein the "further estimated interference levels" are defined), whereas Claim 8 should have referred back to Claims 6 or 7.

3.2 The present formulation of Claim 11 represents an unclear feature combination, as well as it is unclear whether the claim should have depended on Claim 10 or on Claims 1 to 9. After clarification and redrafting of Claim 10 in accordance with the above paragraph 1.2, it appears that Claim 11 in its present form would have no

longer made any sense. However, any additional features not included in the amended Claim 10 that should have been filed (e.g., forming a matrix) could have been made the subject-matter of dependent claims including those features and referring back to Claim 10.

4. Claim 14 is formulated in way contrary to the requirements of Rule 6.2(a) PCT, and should have hence been deleted.

PCT WORLD INTELLECTUAL PROPERTY ORGANIZATION
International Bureau

INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 6 : H04Q 7/34	A1	(11) International Publication Number:	WO 99/31914
		(43) International Publication Date:	24 June 1999 (24.06.99)

(21) International Application Number: PCT/EP98/08120

(22) International Filing Date: 7 December 1998 (07.12.98)

(30) Priority Data:
9726644.9 17 December 1997 (17.12.97) GB

(71) Applicant *(for all designated States except US)*: MOTOROLA LIMITED [GB/GB]; Jays Close, Viables Industrial Estate, Basingstoke, Hampshire RG22 4PL (GB).

(72) Inventor; and
(75) Inventor/Applicant *(for US only)*: MOHEBBI, Behzad [GB/GB]; 12 Cambridge Park Court, Cambridge Park, Twickenham TW1 2JN (GB).

(74) Agents: IBBOTSON, Harry et al.; Motorola, Intellectual Property Operations, Midpoint, Alencon Link, Basingstoke, Hampshire RG21 7PL (GB).

(81) Designated States: BR, US, European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE).

Published
With international search report.
Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments.

(54) Title: A METHOD FOR PREDICTING INTERFERENCE IN A FREQUENCY HOPPING CELLULAR COMMUNICATIONS SYSTEM

(57) Abstract

A method for predicting interference experienced by a first cell (102) from a second cell (104), where both cells (102, 104) have at least one frequency hopping parameter, comprises the steps of determining (step 402) an estimated interference level corresponding to interference experienced by the first cell (102) due to the second cell (104); calculating the probability of the first cell hopping to substantially the same frequency as the second cell; weighting (step 406) the estimated interference level with the calculated probability, and modifying (step 314) the at least one frequency hopping parameter in order modify the weighted estimated interference level.

FOR THE PURPOSES OF INFORMATION ONLY

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

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A METHOD FOR PREDICTING INTERFERENCE IN A FREQUENCY HOPPING CELLULAR COMMUNICATIONS SYSTEM

Field of the Invention

The present invention relates to a method for predicting interference in a communications network, for example, a cellular telecommunications network, such as a Global System for Mobile Communications (GSM) network.

Background of the Invention

When a cellular telephone network is planned, it is known in the art to employ a three cell reuse pattern. Such a pattern comprises a plurality of sites, each of the plurality of sites being divided into three cells and allocated a predetermined number of frequencies for the purpose of frequency hopping. A first cell is allocated a first set of frequencies, a second cell is allocated a second set of frequencies and a third cell is allocated a third set of frequencies. The frequencies and the allocation thereof is identical for each site.

However, such a plan does not account for sources of interference, for example, geographic obstacles and topography of the terrain covered by the network. This often leads to some cells having lower capacity than the majority of cells. The lower capacity cells set a limit on the network capacity as a whole.

It is therefore an object of the present invention to obviate or mitigate the problems associates with frequency planning in a cellular network.

Summary of the Invention

According to a first aspect of the present invention, there is provided, a method for predicting interference experienced by a first cell from a second cell, both cells having at least one frequency hopping parameter, the method comprising the steps of: determining an estimated interference level corresponding to interference experienced by the first cell due to the second

cell; calculating the probability of the first cell hopping to substantially the same frequency as the second cell; weighting the estimated interference level with the calculated probability, and modifying the at least one frequency hopping parameter in order to modify the weighted estimated interference level.

According to a second aspect of the present invention, there is provided a method of optimising calculations corresponding to a first cell in a frequency hopping network, comprising the steps of: fitting a probability model to the probability of cells in the network hopping to substantially the same frequency; determining the cells in the network which have a probability above to a predetermined threshold of hopping to substantially the said frequency, and executing the calculations for the first cell based upon the sources of interference to the first cell which are in the determined cells.

Other, preferred, features and advantages will become apparent from the accompanying dependent claims and the following description.

It is thus possible to provide a method and apparatus for optimising a communications network which has the maximum capacity achievable by controlling the level and probability of interference associated with frequency hopping.

Brief Description of the Drawings

At least one embodiment of the invention will now be described, by way of example, with reference to the accompanying drawings, in which:

FIG. 1 is a schematic diagram of three cells in a cellular network for use with the present invention;

FIG. 2 is a block diagram of frequencies assigned to the three cells of FIG. 1;

FIG. 3 is a flow diagram constituting an embodiment of the present invention;

FIG. 4 is a flow diagram of a step shown in FIG. 3;

FIG. 5 is a flow diagram of an enhancement of FIG. 3, and

FIG. 6 is a probability distribution for use with the enhancement of FIG. 5.

Description of a Preferred Embodiment

A cellular telecommunication network 100 (FIG.1), for example, a GSM network, comprises a first cell 102, a second cell 104 and a third cell 106 having a respective first base station 108, second base station 110 and third base station 112 located therein. The first, second and third cells 102, 104, 106 are, for simplicity of description, omicells, but other cell configurations known in the art can be used. The first, second and third base stations 106, 108, 110 can be M-CELL base stations manufactured by Motorola Limited.

Referring to FIG. 2, a first set of frequencies 200 is allocated to the first cell 102. The first base station 108 operates in a frequency hoping mode and can select any frequency from the first set of frequencies 200 for transmission of a time slot.

A second set of frequencies 202 is allocated to the second cell 104. The second base station 110 operates in a frequency hoping mode and can select any frequency from the second set of frequencies 202 for transmission of a time slot.

Similarly, a third set of frequencies 204 is allocated to the third cell 106. The third base station 112 operates in a frequency hopping mode and can select any frequency from the third set of frequencies 204 for transmission of a time slot.

Operation of the invention will now be described with reference to FIG. 3.

A cell is selected for optimisation (step 300), for example, the first cell 102, by setting a variable, test_cell, equal to 1. The system determines (step 302)

whether a total number of the cells for optimisation, c, have had their corresponding interference level calculated. In the above simplified example, c is equal to 3.

An interference level and associated statistical data for the first cell, I_{cell1}, is calculated (step 304) as follows.

Referring to FIG. 4, an interference matrix $I_{(c,c)}$ is generated (step 402) containing interference levels corresponding to the predicted interference experienced by each cell in the network as a result of other cells in the network. The interference levels can be measured, or estimated using the Netplan software package supplied by Motorola, Inc. The interference matrix $I_{(c,c)}$ has a structure as shown in Table 1 below.

	Cell 1	Cell 2	...	...	...	Cell c
Cell 1	$I_{(1,1)}$	$I_{(1,2)}$	...	...	...	$I_{(1,c)}$
Cell 2	$I_{(2,1)}$	$I_{(2,2)}$	...	...	...	$I_{(2,c)}$
...	...	...	...	...	...	...
...	...	...	...	...	...	...
Cell c	$I_{(c,1)}$	$I_{(c,2)}$	...	...	...	$I_{(c,c)}$

Table 1

When the Netplan software is used, a range of interference levels are generated corresponding to the interference levels at different locations in, for example, the first cell 102. In order to calculate a corresponding single value for each element of the interference matrix $I_{(c,c)}$, it is necessary to process the range of interference levels generated relating to, for example, the first cell 102 in order to obtain the single value corresponding to a nominal interference level. Such processing techniques can include the statistical mode, medium or mean, or the maximum or minimum interference level in, for example, the first cell 102. This processing technique is repeated with appropriate changes so as to calculate each entry in the interference matrix $I_{(c,c)}$. It should be appreciated that other processing techniques known in the art can be used to obtain each single value.

Once the element of the interference matrix $I_{(c,c)}$ has been calculated (step 402), a combination table containing data relating to the possible different combinations of cells interfering with the first cell 102 is generated (step 404) as shown in Table 2 below.

Cell 2	Cell 3
0	0
0	1
1	0
1	1

Table 2

The above table conforms to an incremental binary sequence. Table 2 forms part of a larger table (Table 3) shown below (the last four rows of the columns relating to Cell 2 and Cell 3). However, when optimising the first cell 102, those cells which can interfere with the first cell 102 are only of interest and so the first four rows of the table are ignored.

Cell 1	Cell 2	Cell 3
0	0	0
0	0	1
0	1	0
0	1	1
1	0	0
1	0	1
1	1	0
1	1	1

Table 3

The 1's in the combination table (Table 2) represent the possibility of a cell interfering with the first cell 102. The 0's in the matrix represent the possibility of a cell not interfering with the first cell 102.

Given the frequency allocation of FIG. 2, it is possible to calculate a first probability of the first cell 102 hopping to a substantially identical frequency as the second cell 104.

The first probability can be expressed as:

$P\{h_2\}$ = P{Both cell 1 and cell 2 hop to the same frequency} = P{cells 1 and 2 hop to f_1} OR P{cells 1 and 2 hop to f_2} OR P{cell 1 and 2 hop to f_3}

$$=\frac{1}{4}.\frac{1}{3}+\frac{1}{4}.\frac{1}{3}+\frac{1}{4}.\frac{1}{3}=\frac{1}{4}$$

Similarly, it is also possible to calculate a second probability of the first cell 102 hopping to a substantially identical frequency as the third cell 106.

The second probability can be expressed as:

$P\{h_3\}$ = P{Both cell 1 and cell 3 hop to the same frequency} = P{cells 1 and 3 hop to f_2} OR P{cells 1 and 3 hop to f_3} OR P{cell 1 and 3 hop to f_4}

$$=\frac{1}{4}.\frac{1}{3}+\frac{1}{4}.\frac{1}{3}+\frac{1}{4}.\frac{1}{3}=\frac{1}{4}$$

It should be appreciated that the values of the first and second probabilities will depend upon the number of frequencies in common between the first, second and third sets 200, 202, 204 of frequencies and the number of frequencies used for hopping. The first and second probabilities can be calculated according to any method known in the art.

Each row of the combination table (Table 2) is then analysed to identify cells which could possibly interfere with the first cell 102 and an expected interference value is calculated (step 406) for each row as follows.

An entry in the combination table (Table 2) indicating a possible interference with the first cell 102, i.e. having a '1' in the appropriate location, is identified. Thus, no 1's are present in the first row and so this row contemplates the situation where neither cell 2 nor cell 3 interfere with cell 1. Consequently, an expected interference level of 0 is recorded.

The second row signifies the possible interference between the first cell 102 and the third cell 106 only. The interference level $I_{(1,3)}$ in the interference matrix $I_{(c,c)}$ corresponding to the interference experienced by the first cell 102 due to the third cell 106 is extracted from the interference matrix $I_{c,c}$. If another entry were to exist in the second row of the combination table (Table 2), an additional entry in the interference matrix $I_{(c,c)}$ is identified and extracted.

Once all of the possible interfering cells have been identified for the second row in the combination table (Table 2), the interference levels extracted are multiplied, or weighted, by corresponding probabilities calculated above relating to the probability of two cells hopping to a substantially identical frequency. For example, for the second row of the combination table (Table 2), the calculation will be as follows:

$$p(h_3) \times I_{(1,3)}$$

The same procedure is applied to the third and fourth rows of the combination table (Table 2). Thus, for the third row, the weighted interference level is calculated as follows:

$$p(h_2) \times I_{(1,2)}, \text{ and}$$

for the fourth row, the weighted interface level is calculated as follows:

$$p(h_2) \times I_{(1,2)} + p(h_3) \times I_{(1,3)}$$

The weighted interference levels corresponding to each row of the combination table (Table 2) are then summed in order to generate an interference level corresponding to the possible combination of cells which can interfere with Cell 1.

The next cell to be optimised is then selected by incrementing (step 306) the variable, test_cell. It is then determined whether all the cells have been analysed (step 302), i.e. whether c has been reached.

The above process is then repeated for each cell to be optimised until weighted interference levels have been generated for each of the cells to be optimised.

A probability density function (PDF) corresponding to the weighted interference levels of the cells to be optimised is generated (step 408), for example, using a "bin count" method known in the field of statistics, and a cumulative density function (CDF) is then generated (step 410) using the PDF.

An analytical or visual means for representing the weighted interference levels of the cells is thereby provided.

The poorest performing cells are then identified using either the weighted interference levels or the CDF, and can be optimised by modifying the number and distribution of frequencies (step 314) in order to modify the weighted interference levels so as to obtain an optimum interference level throughout the network.

It should be appreciated that the interference levels are not the only criteria which can be used to optimise the network and other criteria, for example, probability levels can be used.

The above example has been described with reference to three cells for simplicity and clarity. However, it should be appreciated that a greater number of cells can be employed in the network 100.

As a further enhancement (FIG. 5) to the above technique, the interference characteristics of the network 100 can be modelled using a probability distribution, for example, a binomial distribution (step 600).

The binomial distribution can then be used to reduce the number of computations required by determining the number of cells which are likely to contribute significantly to interference experienced by a given cell.

For example, as shown in FIG. 6, the network 100 may comprise 19 cells using 6 identical frequencies for frequency hopping. The binomial distribution for such an arrangement shows that the probability of 10 cells or more using the same frequency at the same time is very low. Therefore, in order to reduce the computational burden, the first 10 strongest interfering cells (which can be determined from the interference matrix $I_{(c,c)}$) can be used (step 602) for network optimisation in accordance with the method described above, instead of using all the cells in the network. An additional modification to the method being that the interference matrix is generated (step 604 and step 606) based upon the selected number of interfering cells.

Since a subset of all possible permutations of cells is only considered, a correction factor can be applied, for example, a simple ratio between the number of permutations ignored and the number of total possible permutations. However, if the contribution to the interference level from the ignored cells is minimal, the correction factor may not be required.

Claims

1. A method for predicting interference experienced by a first cell from a second cell, both cells having at least one frequency hopping parameter, the method comprising the steps of:

determining an estimated interference level corresponding to interference experienced by the first cell due to the second cell;

calculating the probability of the first cell hopping to substantially the same frequency as the second cell;

weighting the estimated interference level with the calculated probability, and

modifying the at least one frequency hopping parameter in order to modify the weighted estimated interference level.

2. A method as claimed in Claim 1, wherein the at least one frequency hopping parameter is the number of frequencies used by the first cell.

3. A method as claimed in Claim 1 or Claim 2, wherein the at least one frequency hopping parameter is the number of frequencies used by the second cell.

4. A method as claimed in any one of the preceding claims, wherein the at least one frequency hopping parameter is the choice of frequencies used for frequency hopping by the first cell.

5. A method as claimed in any one of the preceding claims, wherein the at least one frequency hopping parameter is the choice of frequencies used for frequency hopping by the second cell.

6. A method as claimed in any one of the preceding claims, further comprising providing further cells having further corresponding frequency hopping parameters, and

determining further estimated interference levels corresponding to interference experienced by the first cell due to further cells;

calculating the further probabilities of the first cell hopping to substantially the same frequency as each of the further cells;

weighting the further estimated interference levels with the corresponding calculated further probabilities, and

modifying the at least one frequency hopping parameter in order to optimise the weighted estimated interference level and the further weighted estimated interference levels.

7. A method as claimed in any one of the preceding claims, further comprising forming a matrix including the estimated interference level and the further estimated interference levels.

8. A method as claimed in any one of the preceding claims, further comprising forming a probability density function based on the weighted estimated interference level and the further weighted estimated interference levels.

9. A method as claimed in Claim 9, further comprising forming a cumulative density function based on the probability density function.

10. A method of optimising calculations corresponding to a first cell in a frequency hopping network, comprising the steps of:

fitting a probability model to the probability of cells in the network hopping to substantially the same frequency;

determining the cells in the network which have a probability above to a predetermined threshold of hopping to substantially the said frequency,

executing the calculations for the first cell based upon the sources of interference to the first cell which are in the determined cells.

11. A method as claimed in Claim 10, wherein the calculations are as claimed in any one Claim 1 to 9.

12. A method as claimed in Claim 10 or Claim 11, wherein the determined cells comprise the strongest sources of interference in the network.

13. A method as claimed in any one of Claims 10 to 12, wherein the probability model is a binomial probability model.

14. A method for predicting interference experienced by a first cell from a second cell substantially as hereinbefore described with reference to the accompanying drawings.

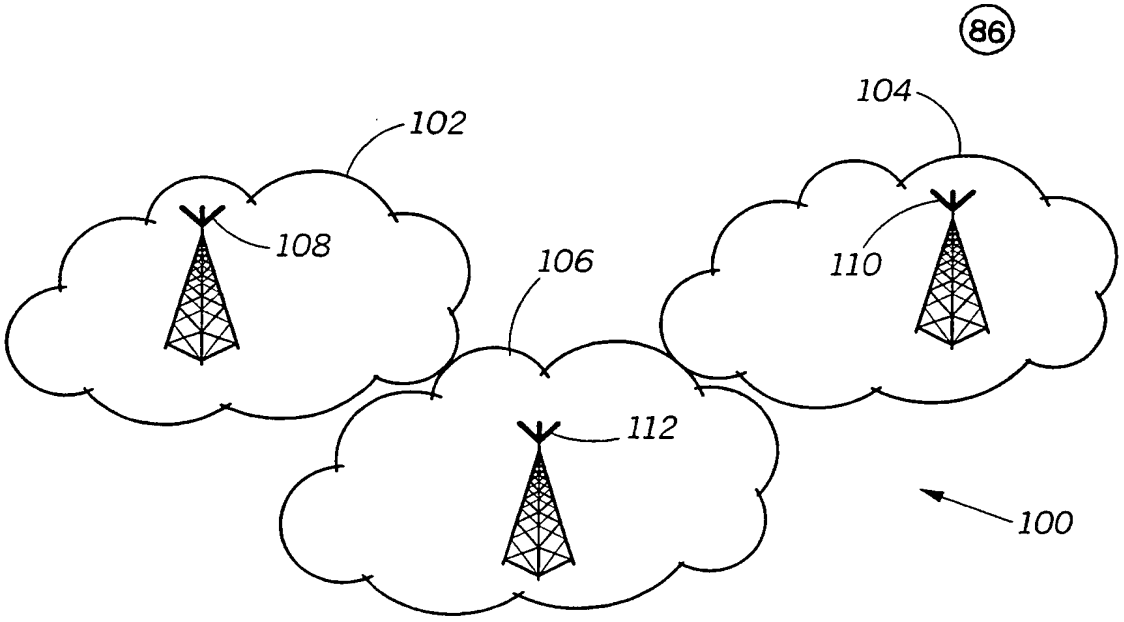
86
104
102
108
106
110
112
100

FIG. 1

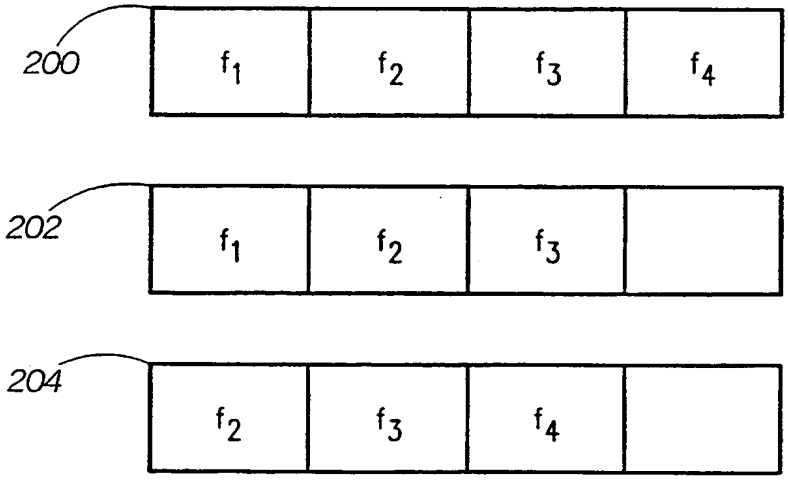
200
f1
f2
f3
f4
202
f1
f2
f3
204
f2
f3
f4

FIG. 2

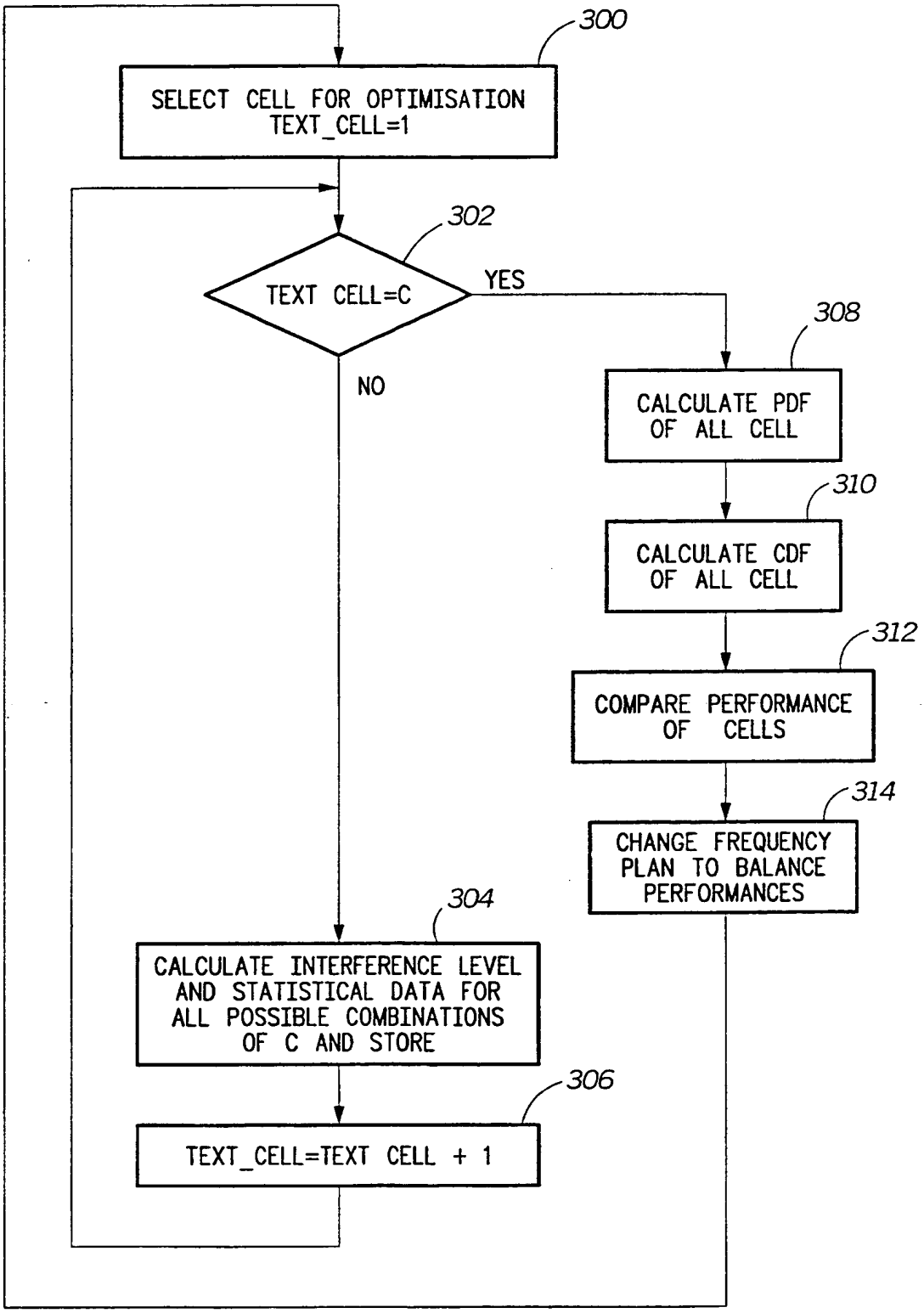
300
SELECT CELL FOR OPTIMISATION
TEXT_CELL=1
302
TEXT CELL=C
YES
NO
308
CALCULATE PDF
OF ALL CELL
310
CALCULATE CDF
OF ALL CELL
312
COMPARE PERFORMANCE
OF CELLS
314
CHANGE FREQUENCY
PLAN TO BALANCE
PERFORMANCES
304
CALCULATE INTERFERENCE LEVEL
AND STATISTICAL DATA FOR
ALL POSSIBLE COMBINATIONS
OF C AND STORE
306
TEXT_CELL=TEXT CELL + 1

FIG. 3

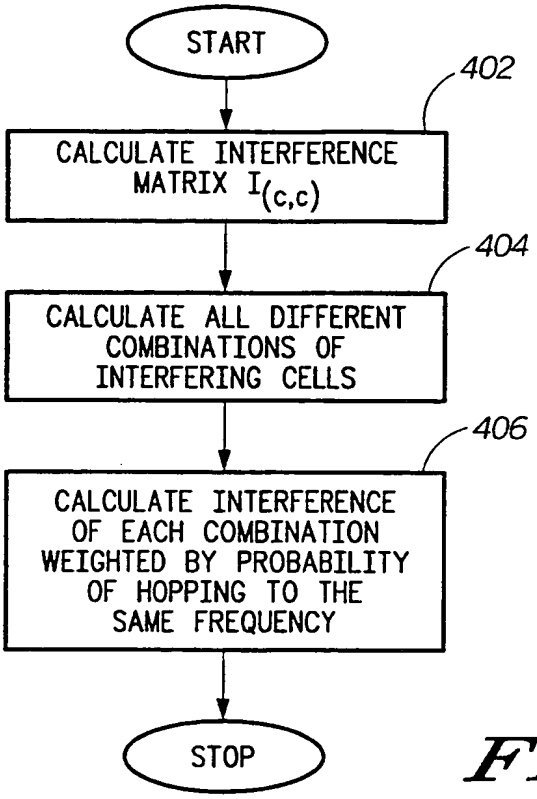

FIG. 4

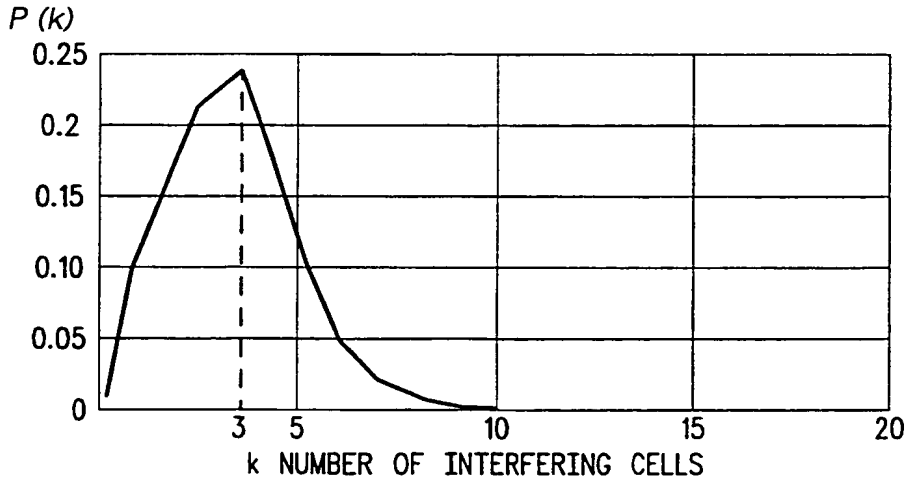

FIG. 6

BINOMIAL DISTRIBUTIN
19 CELLS & 6 FREQUENCIES

$$P(k) = \left(\frac{C!}{k!\,(C-k)!} \right) P^k \left(1-p \right)^{c-k}$$

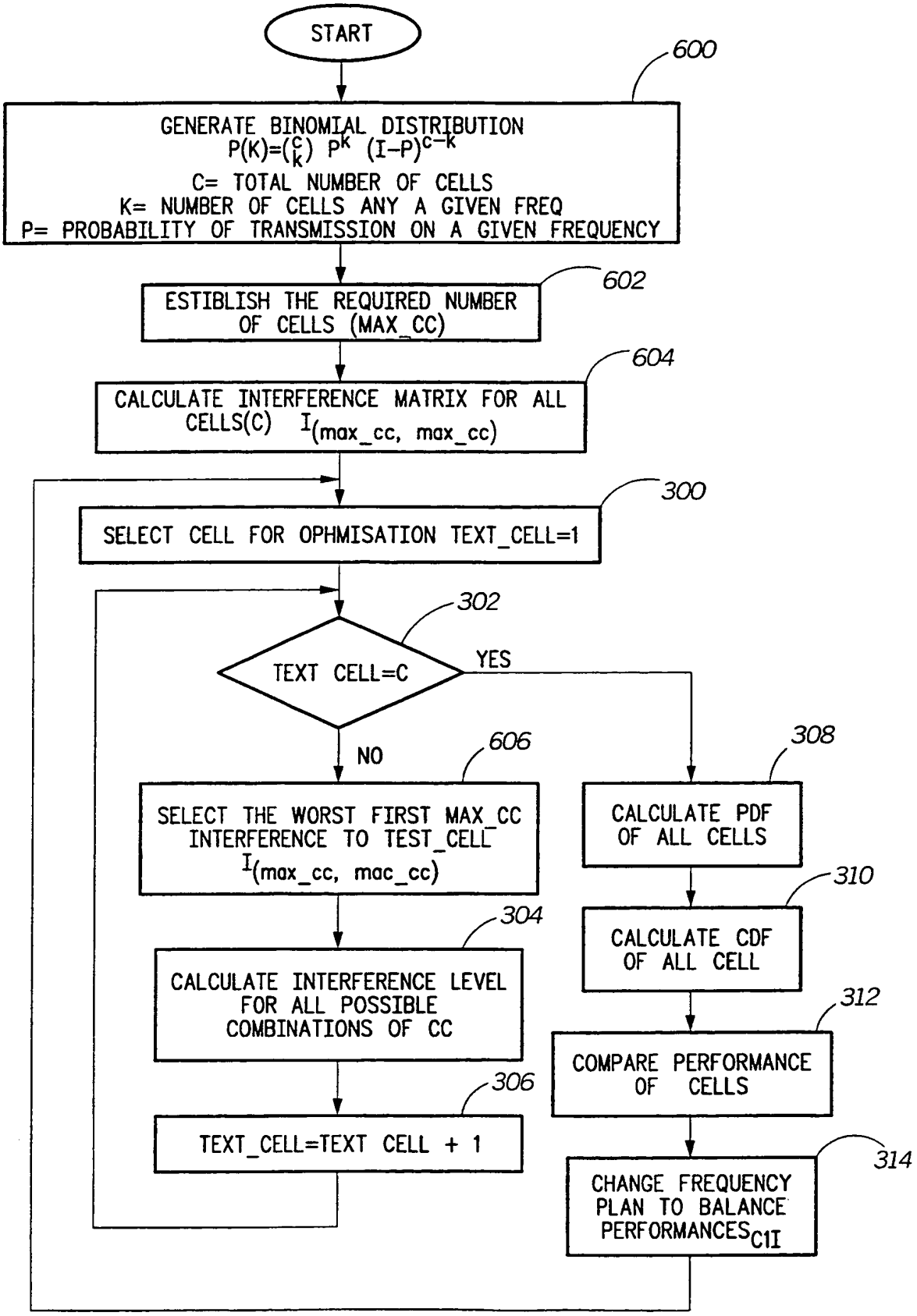
START
600
GENERATE BINOMIAL DISTRIBUTION
$P(K)=\binom{c}{k} P^k (I-P)^{c-k}$
C= TOTAL NUMBER OF CELLS
K= NUMBER OF CELLS ANY A GIVEN FREQ
P= PROBABILITY OF TRANSMISSION ON A GIVEN FREQUENCY
602
ESTIBLISH THE REQUIRED NUMBER OF CELLS (MAX_CC)
604
CALCULATE INTERFERENCE MATRIX FOR ALL CELLS(C) $I_{(max\_cc,\ max\_cc)}$
300
SELECT CELL FOR OPHMISATION TEXT_CELL=1
302
TEXT CELL=C
YES
NO
606
SELECT THE WORST FIRST MAX_CC INTERFERENCE TO TEST_CELL
$I_{(max\_cc,\ mac\_cc)}$
304
CALCULATE INTERFERENCE LEVEL FOR ALL POSSIBLE COMBINATIONS OF CC
306
TEXT_CELL=TEXT CELL + 1
308
CALCULATE PDF OF ALL CELLS
310
CALCULATE CDF OF ALL CELL
312
COMPARE PERFORMANCE OF CELLS
314
CHANGE FREQUENCY PLAN TO BALANCE PERFORMANCES$_{C1I}$

FIG. 5

INTERNATIONAL SEARCH REPORT

International Application No
PCT/EP 98/08120

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 H04Q7/34

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 H04Q

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	WO 94 05097 A (STJERNHOLM PAUL ;TELEVERKET (SE)) 3 March 1994 see page 2, line 25 - page 4, line 33	1,10
A	US 5 293 640 A (GUNMAR KRISTER ET AL) 8 March 1994	

☐ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

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"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
26 April 1999	04/05/1999

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Lopez-Pérez, M-C

Form PCT/ISA/210 (second sheet) (July 1992)

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
PCT/EP 98/08120

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